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DIELECTRIC CHARACTERISTICS OF SYNTACT MATERIALS BASED ON HOLLOW CERAMIC MICROSPHERES WITH ORGANOSILICON BINDERS

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The problems of using hollow ceramic microspheres based on smoke emissions generated by power plants to obtain syntact materials with increased dielectric characteristics are considered. Comparative dielectric properties of the materials considered and materials based on hollow glass microspheres are described.

Earlier published papers [1, 2] considered syntact materials (SM) based on hollow sodium-borosilicate glass microspheres and organosilicon binders of different types. SM have high strength parameters combined with a low density and high thermophysical parameters, However, studying the possibility of using these composites as dielectric materials, it was found that the electric characteristics of such SM are rather low [3]. This is especially evident in the range of superhigh radio frequencies (over 300 MHz). Another factor restricting the wide application of glass microspheres is their high cost. In this context, the use of hollow ceramic microspheres (HCM) as fillers is of special interest. These materials abroad got the name of cenospheres. HCM represent a part of the smoke emission of thermal power plants burning coal or peat.

The purpose of our research was to study the dielectric properties of SM containing HCM as the filler, the binder being oligooxyhydride silmethylene-siloxysilane (OHSMS) produced in experimental batches at the Silan JSC (town of Donkov). A specific feature of this binder is its facile transformation into ceramics at relatively low temperatures (500 – 700°C).

Samples were prepared by mixing an OHSMS solution in an organic solvent, molding at a low pressure, and subsequent heat treatment. The preparation of SM considered is described in detail in [1]. The dielectric parameters were measured in a cavity resonator at a frequency of 9.8 HHz according to the requirements of GOST 8544.

The dielectric properties of SM with the OHSMS binder to a large extent should depend on the nature of the binder and the filler and on their ratio. There is an analytical relationship (the Lichteneker formula) for heterogeneous systems correlating the dielectric permeability of a composite with the dielectric permeability of its components:

$$\ln \varepsilon_r = \theta_1 \ln \varepsilon_{r1} + \theta_2 \ln \varepsilon_{r2} ,$$

where ε_{r1} and ε_{r2} are the dielectric permeabilities of the 1st and the 2nd components, respectively; θ_1 and θ_2 are the volume fractions of the 1st and the 2nd components, respectively.

Table 1 gives experimental and estimated values of the dielectric permeability of SM with fillers represented by HCM and HGM (hollow glass microspheres).

The estimated values of dielectric permeability are lower than the experimental values, which may be due to the presence of sorbed moisture ($\varepsilon_r = 81$), as a consequence of the formation of open pores in SM with a low volume concentration of OHSMS.

A comparison of the estimated and experimental dielectric permeability values shows that the difference is more perceptible in SM using glass microspheres as fillers.

With increasing OHSMS content in a syntact material, the dielectric loss tangent grows to a lesser extent in the case of ceramic microspheres than in using glass microspheres.

TABLE 1

OHSMS content, vol.%	Dielectric permeability			
	estimated		experimental	
	HGM	HCM	HGM	HCM
10	1.24	1.21	1.32	1.27
15	1.37	1.34	1.43	1.36
20	1.48	1.43	1.52	1.45
25	1.67	1.61	1.70	1.63

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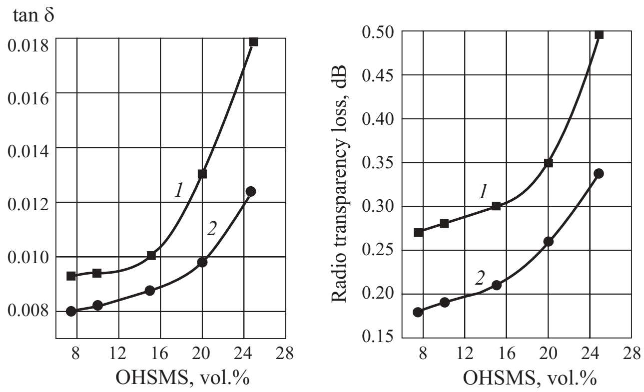

Fig. 1. Dependence of the loss-angle tangent and loss of radio transparency of the material on its OHSMS content: *1*) HGM; *2*) HCM.

The same effect is observed in measuring the loss of radio transparency in the material (Fig. 1).

It is found that the dielectric characteristics of SM filled by HCM in all cases is perceptibly better than in SM filled by glass spheres. This fact may seem contradictory, since the density of a composite with a HCM filler is 1.3 – 1.5 higher, and the loss of radio transparency theoretically should grow when SHS radio waves pass through a denser medium.

However, one should take into account the fact that HCM, in contrast to HGM, contain a minimal quantity of alkali and alkali-earth metal ions, which, as rule, do not contribute to high dielectric parameters. This is related to the increasing surface resistivity of the filler both in a moist atmosphere and under the effect of aggressive reactants: hydrogen chloride, sulfur dioxide and trioxide, etc.

The chemical analysis of HCM identified their chemical composition as follows (wt.%): 57.0 SiO_2, 28.0 Al_2O_3, 3.0 CaO, 1.4 MgO, 2.3 Na_2O, 4.8 Fe_2O_3, and 5.0 carbon and other components.

Compared to glass microspheres, HCM contain a substantial amount of silica, which is known to be a dielectric with a very low loss-angle tangent and a low-mobility aluminum ion. In this case the use of HCM as a filler due to the absence of highly mobile alkali metal ions makes it possible to produce composite material with dielectric characteristics little depending on variations in the external conditions (temperature, moisture).

Thus, it becomes possible to produce relatively inexpensive but sufficiently effective radio-transparent syntact materials based on hollow ceramic microspheres, which may be used in various spheres of science and engineering. At the same time it contributes to solving environmental problems related to the utilization of smoke emission.

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